Demonstration of iTaSC as a unified framework for task specification, control, and coordination for mobile manipulation

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***Abstract*— Our demonstration involves a mobile co-manipulation task of a PR2 robot and a human, in which they manipulate an object together in a cluttered environment with dynamic and static objects. The PR2 should assist the human in carrying the co-manipulated object and follow the indications of the human (by estimating the intended object motion from the forces excerted by the human), avoid the static and dynamic obstacles, prevent collisions of the co-manipulated object with the human, keep visual contact with the operator, and prevent unnatural poses. In the proposed co-manipulation demonstration we will present (i) the advantages of the iTaSC–Skills framework [7] for task specification over traditional motion methodologies, and (ii) the developed iTaSC–Skill software, founded on the real-time Orocos [1] framework, allowing easy specification and code-generation for the co-manipulation task.**

The demonstration is linked to but also goes beyond *paper 1221* [4].

Keywords: *mobile manipulation, task specification, shared control, software*

I. Introduction

The habitat of robotic systems is evolving from industrial work cells to domestic, cluttered, and populated environments. To cope with the increasing uncertainties in these environments and the complexity of the applications, six-degree-of-freedom industrial manipulators are being replaced by mobile platforms with two redundant arms, both equipped with numerous sensors. To deal with the increasing complexity of robotic systems as well as the increasing uncertainty and dynamics of the robotic system's environment, a highly modular methodology for motion specification and coordination is very important.

Our demonstration involves a mobile co-manipulation task of a PR2 robot and a human (Figure 1), in which they manipulate an object together in a cluttered environment with dynamic and static objects. The PR2 should assist the human in carrying the co-manipulated object and follow the indications of the human (by estimating the intended object motion from the forces excerted by the human), avoid the static and dynamic obstacles, prevent collisions of the co-manipulated object with the human, keep visual contact with the operator, and prevent unnatural poses.

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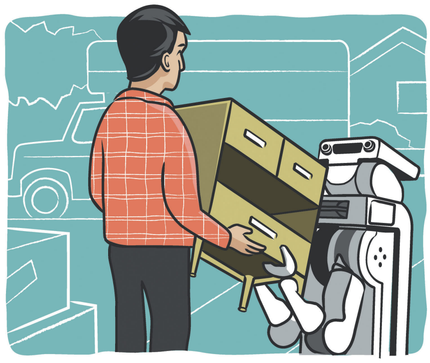

Fig. 1. Co-manipulation by a human and a robot

II. Technology used

While the demonstration is focused on co-manipulation it presents several open-source software packages to enable the use of a *Unified framework for task specification, control, and coordination* on the PR2 and any other robot. The unified framework is based on ***iTaSC***,or **i**nstantaneous **Ta**sk **S**pecification using **C**onstraints, [2], [5] is such a modular motion specification framework, developed at the K.U.Leuven during the last years. iTaSC synthesizes motions by specifying *constraints* as the possible interactions between the robot and the environment that are important for the task at hand. The iTaSC methodology specifies constraints on geometric, dynamic and sensor-space relationships between objects (*object frames*) and their features (*feature frames*). The framework can be used for any robotic system, including various kinds of sensors.

The advantages of iTaSC over traditional motion specification methodologies, that will be demonstrated during the mobile co-manipulation task are: (i) *Composability of constraints*: constraints do not span a full 6D desired relation between two objects, but usually only specify a *partial* relationship, so multiple constraints between different objects can easily be composed; (ii) *Reusability of constraint specifications*: constraints are defined between *features frames* with a semantic meaning in the context of a *task*, hence the task specification can be reused on different objects; and (iii) *Automatic derivation of the control solution*: iTaSC facilitates automatic derivation of controllers from the constraint specification by generating a robot motion that instantaneously optimizes the constraints.

To this end we will present the different constraints needed to complete the mobile co-manipulation in unstructured environment tasks and the effect of changing the priorities and weights of the different constraints.

iTaSC supports a modular *coordination* framework to create motion and estimation ***Skills***. **Skills** are the components in a robot control system that are responsible for the *coordinated execution* and *parameter configuration* of several iTaSCs *instantaneous robot motion specifications*, such that, together, they make the robot system realize a given task in a given environment [9].

The combined iTaSC–Skills framework shows its true power at high complexities of the application and the robotic system. The skills are implemented as *Finite State Machines* (FSM) and provide the decoupling between the continuous level of the motion specification and the discrete level of motion coordination. The reusability of skills in different applications executed by different robotic platforms is maximized by using the iTaSC formalism as the underlying methodology. Skills coordinate only a limited set of constraints; only those constraints that together form a *functional motion* are coordinated by the Skill's FSM. The framework will be illustrated by the mobile human-robot co-manipulation demonstration using the PR2 involving the following skills (i) co-manipulation of the manipulation object with the operator, (ii) avoiding static and dynamic obstacles in the unstructured environment, (iii) visual contact with the operator, and (iv) configuration constraints to prevent unnatural poses of the PR2.

The final goal of the demonstration is to present the iTaSC software, based on the Orocos project but integrated with ROS. **The Orocos project** contains a *RealTime Toolkit* (RTT) subproject that allows us to control a robotic system using a hard-realtime-capable operating system, e.g., RTAI-Linux or Xenomai-Linux. RTT allows the execution of scripted FSMs in hard realtime. These scripted FSMs are the basis for the Skill implementation, that can, by using RTT and a hard realtime capable operating system, be executed in hard realtime. The seamless integration with ROS is realized through the orocos-ros-integration [8].

In the mobile human-robot co-manipulation demonstration we will present the ***iTaSC–Skill software***, with a focus to: (i) the *modularity* of the software design, allowing the user to implement their own solver, scene graph (robots, objects, ...), motion generators, ..., (ii) the *flexible user interface*, allowing to add or remove constraints and change priorities and weights of constraints, and (iii) the *modularity of the task specification*, allowing to share and reuse tasks (or subtaks), and paving the road for a task-web application allowing to download and upload different tasks.

Additionally, to complete the different co-manipulation task we will use: a face detector, allowing the robot to make visual contact with the operator, the Bayesian filtering library [3], used to process the results of the face detector to retrieve a stable estimate of the pose of the operator's head and to process the laser scanner measurements in order to estimate the pose of the operator, and the Kinematics and Dynamics library [6], to specify the kinematics and dynamics of both the robot and the virtual kinematic chains involved in the iTaSC specification.

Additional information including a discussion on the iTaSC–Skill software design, a teaser movie is available at `http://people.mech.kuleuven.be/~tdelaet/irosDemo`.

III. Demonstration live and interactive aspects

The mobile PR2-human co-manipulation will be demonstrated live. Everyone will be allowed to perform the co-manipulation with the PR2. Additionally, everyone will be allowed to change the task specification by adding or removing constraints and changing the priorities and weights of the subtasks. The effects of changing the task specification will be directly observable for the operator, but are also visible from the PR2's way of acting and we will provide visual feedback on the performance (which constraints are violated, ...), such that bystander can also appreciate the demonstration.

IV. Standard platform demo requirements

a) Robot hardware platform: PR2

b) Sensor requirements: We will use the different sensors available on the PR2: (i) the head cameras in order to find the face of the manipulator, (ii) the hokuyo laser scanner on the base to avoid obstacles in the environment, and (iii) the tilting laser scanner to follow the operator. Additionally we will use a JR3 force/torque sensor (which we bring ourselves) to evaluate the interaction forces between the PR2 and the manipulated object in order to show the difference between different task specifications.

c) Computational requirements: We will use the computers of the PR2 and our own laptops.

d) Equipment we will bring: two laptops, JR3 force/torque sensor, co-manipulation object.

e) Special requirements: We will need some space to manoeuver such that the operator can perform the mobile co-manipulation task together with the PR2. We would like to have a large screen or projector to show (i) the iTaSC software interface to specify the co-manipulation task, (ii) performance plots of the co-manipulation task, and (iii) online sensor output. Additionally we will need wireless communication between our laptops and the PR2.

f) Number of people expected to support the demo: three (Dominick Vanthienen, Koen Buys, and Steven Bellens or Markus Klotzbücher)

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see `http://people.mech.kuleuven.be/~tdelaet/irosDemo`.

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